FINAL REPORT

MARS GCMS/DRILL MONTGOLFIERE MICROMISSION PAYLOAD CONFIGURATION

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SUMMARY

This study was conducted to show how a combination Gas Chromatograph/Mass Spectrometer (GCMS) and drill payload would be distributed within the constrained volume of a Mars Micromission entry vehicle. The entry vehicle is equipped with a Montgolfiere balloon landing system, developed by Jet Propulsion Laboratory. Using solar heat, the balloon will allow the payload to slowly impact the martian surface at about 9 m/sec, with Pathfinder-like air bags absorbing the force of impact. After the payload lands, it is disconnected from the balloon, and the balloon rises to provide imaging and science measurements for the remainder of the day (2007 mission only). Total entry vehicle mass is less than the allowed 40 kg for a 2005 micromission launch, and below 45 kg for a 2007 micromission launch. After landing the GCMS payload, an attached drill, developed by Honeybee Robotics, deploys and extends, while drilling over one m into the martian soil. Soil samples are retrieved and analyzed with the onboard GCMS. The main payload camera system is composed of three cameras, which are used to witness the descent of the vehicle on the Mars surface, to observe the surroundings near the landing site, and to image the drilling activity.

AutoCAD 3D solid modeling have been used to place all components needed for this mission into the constrained volume of a Mars micromission. AutoCAD's capability to detect any interference between objects was used to confirm that all components fit within our payload volume constraints.

INTRODUCTION

The goal of this Mars micromission is to soft-land a GCMS/Drill payload via a solar balloon, collect a soil sample 1.2 meter below the surface and analyze the soil onboard with the GCMS. This mission combines a solar Montgolfiere hot air balloon developed by the Jet Propulsion Laboratory (JPL), a GCMS developed by Goddard Space Flight Center (GSFC), and a drill developed by Honeybee Robotics. The drill can perforate 1.2 meters below the surface and extract soil samples, which are transported to the GCMS for analysis. The camera system on board the GCMS payload consists of three cameras, and is described below.

BALLOON

The solar balloon is also called a solar Montgolfiere balloon, in honor of the French Montgolfier brothers who flew the world's first hot air balloon over two centuries ago. It is constructed of 3.5 micron mylar with a kevlar scrim and has a hole in the bottom to allow filling with ambient air while initially falling (Figure 1). Scrim is glued to the Mylar to increase strength and to reduce the tearing of the mylar. Testing of a number of solar balloons was initiated in 1997 and is continuing through 2000. The tests have deployed balloons at 8-10 mbar (~35 km altitude) to simulate the density of the

Martian atmosphere. The balloons have filled with ambient air in approximately 1-2 minutes, and attained full buoyancy after an additional minute. Solar Montgolfiere deployment test results are summarized in Table 1.

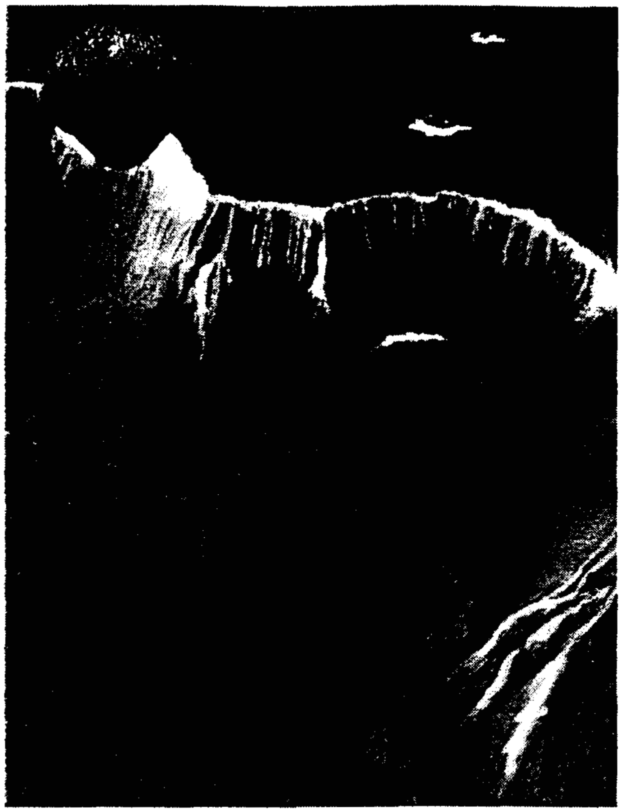

Figure 1. Mars Solar Montgolfiere

CAMERA

The camera design described in Reference 2 is also being assumed for all cameras in this system. A total of three cameras will be on board the GCMS payload. The first camera is used to observe the descent of the vehicle. The second camera is dedicated to capture images of the Mars surroundings, and the third camera is used to view the drilling of the Mars surface. All components needed for camera operation including imaging, data storage, communication, and batteries, weigh 875 grams with a required power consumption of 10 W-hrs.

DRILL

The drill used in this study is designed by Honeybee Robotics (Reference 3). The drill is 60 cm in length while stowed away horizontally in the payload. When the payload lands on the

Mars surface, the drill is then rotated into the vertical drilling position. Once in position, the drill extends to a 1-1.2 meter configuration. Figure 2 contains the step-by-step process for the drill from the stowed to the fully extended configuration.

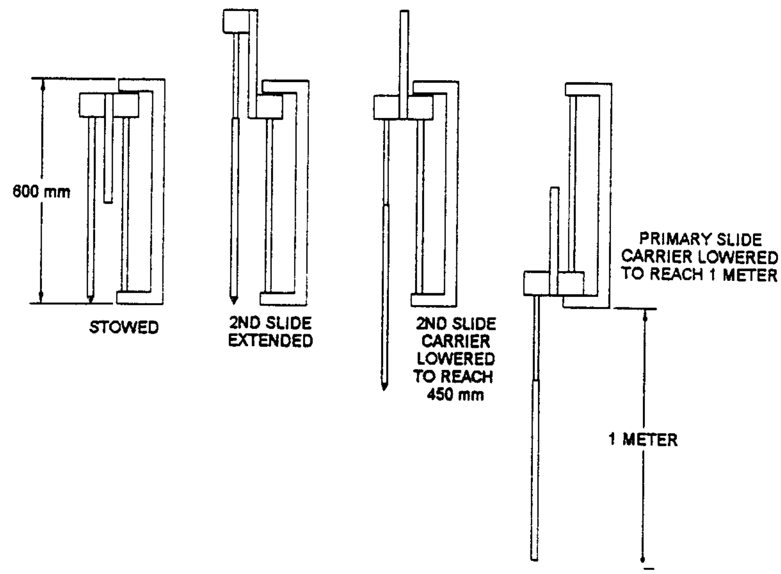

Figure 2. Honeybee Drill Deployment

BATTERY

A primary battery is needed to provide approximately 100 W-hrs of power to the main payload. The following is the breakdown of the power usage.

- 20 Watts for the GCMS experiment for 1.5 hours.
- 20 Watts for the drilling operation for 1.5 hours.
- 20 Watts for camera operation for 2 hours.

Primary battery properties are as follows: 250W-hr/Kg and 500 W-hr/L (Reference 5). A battery capable of providing the required power of 100W-hrs takes up a volume of 200 cm^3 and weigh 400 grams.

AIRBAGS

Airbags, similar to those used on Pathfinder, are used to absorb the impact in the Mars landing. In this study, there are six airbags that create an ellipsoid shape once deployed. The center of mass of the payload is below the center of the ellipsoid formed by the airbags. This will keep the payload in a correct gravity orientation after landing. The airbags are a multi-layer construction consisting of an inner bladder layer and up to four outer layers for abrasion protection. The bladder layer is a 4.3oz/yd^2 silicone-coated Vectran fabric, while the four outer abrasion layers are made of 2.4 oz/yd^2 modified ripstop weave Vectran fabric (Reference 6). A deployed configuration is shown in Figure 3 with some of the airbags shown in the third sketch.

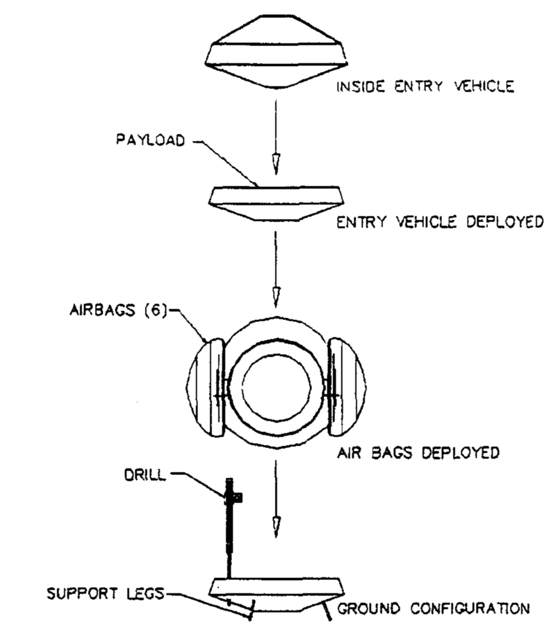

Figure 3. GCMS/Drill Payload Deployment

SUPPORT LEGS

The payload is equipped with spring activated legs to provide stability to the payload after landing. The legs also prevent the payload from shifting position due to the torque applied by the drilling process. Three legs are located 120 degrees apart and will be deployed seconds before impact. The location of the legs can be seen in Figure 3.

COLD GAS SPIN UP SYSTEM

The cold gas spin up system is similar to that proposed for the Kitty Hawk Mars airplane proposal (Reference 4). It consists of small cold gas propellant tanks and thrusters located near the top corners of the entry vehicle. Opening a valve will allow the gas to exit through a nozzle and produce enough thrust to spin the entry vehicle. Spin up rate of the entry vehicle is approximately 3-5 rev/min. The location of the gas tanks is shown in Figure 4.

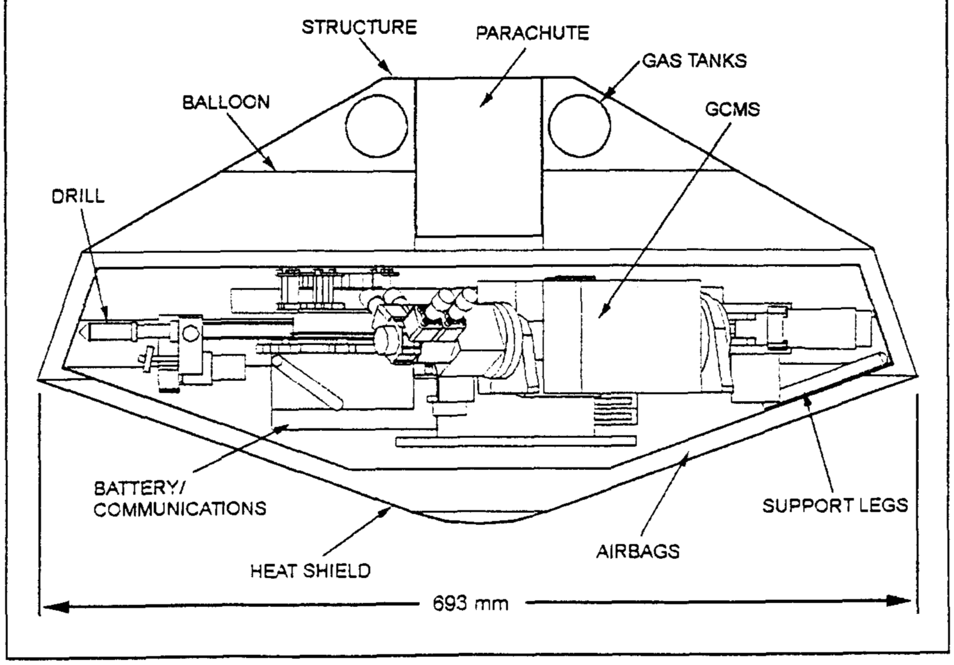

Figure 4. Entry Vehicle Cross

PAYLOAD

Table 2 contains a mass breakdown of the components for a 2005 launch, which allow for a Mars entry vehicle mass of 40 kg, as well as for a 2007 launch, which allows for an entry vehicle mass of 45 kg. All sketches apply to both the 2005 and 2007 missions. In the 2005 mission, the Montgolfiere balloon is discarded after landing the GCMS/Drill payload, while in the 2007 mission, the Montgolfier re-ascends after landing the GCMS/Drill (Figure 5). The balloon then goes on to provide imaging and science measurements for the remainder of the day. Kim Leschly (Reference 7) has provided the dimensions of a micromission standard probe volume (or entry vehicle volume).
The locations of all components are shown in Figure 4. The envelope volumes of major components are listed in Table 3, but do not represent further compaction possible during spacecraft assembly.

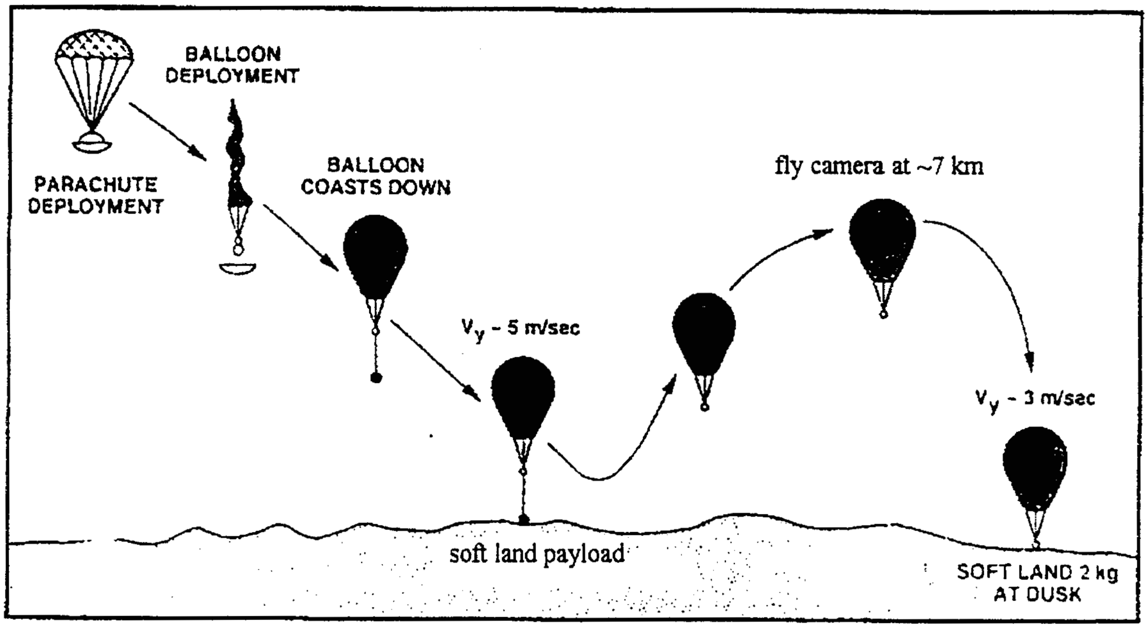

Figure 5. An example descent and reascent scenario is illustrated for a Montgolfiere Mars entry.

REFERENCES

1) Jack A. Jones, Jiunn Jeng Wu, "Solar Montgolfiere Balloons for Mars," Jet Propulsion Laboratory, 1999.
2) Dr. Robert Zubrin, Principal Investigator, "Final Report for the Mars Micro Balloon Probe SBIR Phase 1 Study," Pioneer Astronautics, October 8, 1998.
3) Private Communication, Stephen Gorevan, Honeybee Robotics.
4) Private Communication, Mark Herring, Jet Propulsion Laboratory.
5) Private Communication, Marshall Smart, Jet Propulsion Laboratory.
6) Electronic Mail Document, Airbag System Mass Estimate, Chuck Sandy, ILC Dover, Inc, February 5, 1998
7) Kim Leschly, "Mars Micromission Overview", Jet Propulsion Laboratory, June 3, 1999

TABLE 1
SOLAR MONTGOLFIERE TEST FLIGHTS
Jack A. Jones (Updated November 11, 1999)

Test	Date	(m) Diam.	Balloon Material	Shape	(microns) Thickness	Results
SM1	09/97	5	Black Poly	Cylinder	12	Success – Deployed from ground in Mojave Desert
SM2	10/97	5	Black Poly	Cylinder	12	Success – Deployed from ground at Catalina Island
SM3	12/97	5	Black Poly	Cylinder	12	Success – Drop deployed from hot air balloon
SM4	07/98	15	Clear Poly	Cylinder	8	Successful high altitude systems check with expected failure of non-reinforced commercial balloon
SM5	07/98	6	Black Poly	Cylinder	8	Success – Although deployed at lower alt. than expected
SM6	10/98	8	Mylar/Scrim	Natural	6	Success – Deployed and stabilized as predicted
~~SM7~~	10/98	15	Black Poly	Cylinder	12	Deployment failure due to top-heavy fabrication
SM8	08/99	15	Black Poly	Natural	15	Successful deployment and fill, but lower stabilization altitude due to some lower balloon damage
SM9	09/99	15	Mylar/Scrim	Natural	6	Successful deployment and fill, but failed to stabilize due to adhesive tape detachment from gores
FUTURE FLIGHTS						
SM10	12/99	15	Mylar/Scrim	Natural	6	New heat-seal tape and streamlined payloads
SM11	02/00	6	Mylar/Scrim	Natural	3.5	Ultra light-weight glued gores (7.2 gm/m2) with streamlined payloads
SM12	03/00	6	Mylar/Scrim	Natural	3.5	

Data + Assembly →
Assembly →
Data + Assembly →
Data + Assembly →

TABLE 2
PRELIMINARY MASS SUMMARY FOR MARS GCMS/MONTGOLFIERE MICROMISSION

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Component	Kg Mass (2005)	Kg Mass (2007)
Payload (55% of entry mass)		
GCMS	8.0	8.0
Drill	2.0	2.0
Communications/Battery	1.0	1.0
Montgolfiere (@ 9 gm/m^2)*	2.0	3.5
Gondola	0.0	1.0
Air Bags**	3.0	2.5
Subtotal	16.0	18.0
30% Margin	4.8	5.4
Payload Total	20.8	23.4
Entry Vehicle (45% of entry mass)		
Shield, Cover, Parachute, etc.	15.7	17.7
Release Mechanism	2.4	2.7
TOTAL MASS (Kg)	38.9	43.8
MAX ALLOWABLE	40.0	45.0
Vertical Impact Velocity	9.0 m/sec	7.3 m/sec
Postlanding Montgolfiere Mission	No	Yes

* Solar Montgolfieres have now been fabricated with 7.2 gm/m^2 total envelope mass density (3.5 micron mylar with thin kevlar mesh and minimal gore seams) and will be tested in FY '00. Solar Montgolfiere temperature = 140°C.

** Air Bags assume a horizontal wind <10 m/sec during surface impact.

TABLE 3
Micromission Component Envelope Volumes

Component	Volume (cm3)
Camera/Communications	700
GCMS/Drill	25000
Solar Balloon	17000
Air Bags	12000
Battery	200
Subtotal	54900